PATENT
Customer No. 22,852
Attorney Docket No. 08513.7019-00000

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Pichler et al.

Application No.: 09/508,034

Filed: June 6, 2000

For: SELF-ASSEMBLED TRANSPORT LAYERS FOR OLEDS

Group Art Unit: 2879

Examiner: M.P. Hodges

Commissioner for Patents
Washington, DC 20231

Sir:

TRANSMITTAL LETTER

Enclosed is a reply to the Office Action of December 4, 2002. The item(s) checked below are appropriate:

The claims are calculated below:

	Claims Remaining After Amendment		Highest Number Previously Paid	Present Extra	Rate	Additional Fee
Total	49	-	49	0	x $ 18	$ 0
Indep.	7	-	7	0	x $ 84	0
☐ First Presentation of Multiple Dep. Claim(s)					+$280	0
					Subtotal	$ 0
					Reduction by ½ if small entity	- 0
					TOTAL	$ 0

Please grant any extensions of time required to enter this response and charge any additional required fees to our deposit account 06-0916.

Dated: March 3, 2003

By: Therese A. Hendricks

Therese A. Hendricks
Reg. No. 30,389

FINNEGAN
HENDERSON
FARABOW
GARRETT &
DUNNER LLP

1300 I Street, NW
Washington, DC 20005
202.408.4000
Fax 202.408.4400
www.finnegan.com

SELF-ASSEMBLED TRANSPORT LAYERS FOR OLEDs

Field of the Invention

The present invention relates to an improved fabrication process for organic light-emitting devices, and a structure formed thereby.

Background of the Invention

Organic light-emitting devices (OLEDs) such as described in earlier US patent No. 5,247,190 assigned to Cambridge Display Technology Limited, or in Van Slyke et al., US Patent No. 4,539,507, the contents of which are herein incorporated by reference and example, have great potential for use in various display applications, such as large-area flat-panel displays. Principally, an OLED consists of an anode that injects positive charge carriers, a cathode that injects negative charge carriers and at least one organic electroluminescent layer sandwiched between the two electrodes. Under application of a positive bias to the anode, holes are injected from the anode and electrons from the cathode. These carriers recombine within the organic electroluminescent layer, giving out light.

Typically, although not necessarily, the anode is a thin film of, for example, indium-tin-oxide (ITO), which is a semi-transparent conductive oxide, which is commercially readily available already, deposited on glass or plastic substrates. The organic layer(s), typically a thin (100 - 1000 nm) layer of conjugated polymer, is normally deposited onto the ITO-coated substrate by, for example, evaporation, or any one of spin-coating, blade-coating, dip-coating or meniscus-coating. The final step of depositing the cathode layer, typically a low work-function metal electrode, onto the organic layer is normally performed by thermal evaporation or sputtering of a suitable cathode metal. Layers of Al, Ca or alloys of Mg:Ag or Mg:In or Al alloys are often used as cathode materials.

One of the key advantages of the OLED technology is that devices can be operated at low drive voltages, provided that suitable electro-luminescent organic layers, and electrodes with good

Polymer light emitting devices fabricated using a self-assembly process are described in A. C. Fou, O. Onitsuka, M. Ferreira and M. F. Rubner, "Interlayer interactions in self-assembled poly(phenylenevinylene) multilayer heterostructures: implications for light-emitting and photorectifying diodes," Mat. Res. Soc. Symp. Proc., Vol. 369, pp. 575-580, 1995; and A. C. Fou, O. Onitsuka, M. Ferreira, M. F. Rubner and B. R. Hsieh, "Fabrication and properties of light-emitting diodes based on self-assembled multilayers of poly(phenylene vinylene)," J. Appl. Phys., Vol. 79, pp. 7501-7509, 1996.

In these references a technique of self-assembly is utilised using polycations and polyanions described in G. Decher, J. D. Hong and J. Schmitt, "Buildup of ultrathin multilayer films by a self-assembly process. 3. Consecutively alternating adsorption of anionic and cationic polyelectrolytes on charged surfaces," Thin Solid Films, Vol. 210, pp. 831-835, 1992. In these structures PPV precursor or its derivatives are used as the polycation, with various polyanions such as polystyrenesulfonate or sulphiniated polyaniline. Poly(*p*-pyridylvinylene) and its derivatives have also been used to make self-assembled LEDs.

The process of producing by self-assembly a film of sufficient thickness to give a working LED is extremely time-consuming, due to the number of dipping and rinsing steps involved. In the work described above, the entire device was completed by self-assembly, thus retaining the problem of many dipping steps. This method is unlikely to be commercially viable.

Summary of the Invention

It is therefore an object of the present invention to provide a structure, and fabrication process, in which a well-defined, thin, polymer interfacial layer may be provided between an electrode and the electroluminescent material of an OLED without unduly inhibiting the standard commercial fabrication process.

Thus, according to a first aspect of the present invention there is provided a method of fabricating an organic light-emitting

assembled using the same coupling agent.

Quaternisation and oxidation techniques are described, for example, in J. March, "Advanced Organic Chemistry: Reactions, Mechanisms and Structure", 3rd Ed., John Wiley & Sons, New York, 1985, Chapters 10 and 19.

As a result of either the quaternisation or the oxidation processes according to the third aspect of the invention, the resultant coupling agents advantageously have greatly reduced susceptibility to oxidation, a process that can be a problem in devices.

Brief Description of the Drawings

The invention will now be described with reference to the accompanying drawings in which:

Figure 1 illustrates an OLED fabricated in accordance with the present invention;

Figure 2 illustrates examples of the composition of particular layers of the structure of Figure 1;

Figure 3 illustrates the efficiency obtained by described examples of devices according to the present invention;

Figure 4 illustrates the power efficiency obtained by described examples of devices according to the present invention;

Figure 5 illustrates the luminance obtained by described examples of devices according to the present invention;

Figure 6 is a schematic cross-sectional view of a device having 5BTF8 (F8 doped with 5% F8BT) as the emitting material;

Figure 7 shows the chemical structures of poly(styrenesulphonic acid) doped poly(ethylenedioxythiophene) (PEDOT-PSS), poly(2,7-(9,9-di-*n*-octylfluorene)) (F8), and poly(2,7-(9,9-di-*n*-

octylfluorene)-3,6-benzothiadiazole) (F8BT);

Figure 8 shows the chemical structure of a silyl coupling layer;

Figure 9 shows UV-visible absorption spectroscopy measurements of the assembly solutions for devices I to IV;

Figures 10-14 show the current and light-output performance an efficiency against voltage of devices I-V respectively;

Figure 15 shows the power efficiency of devices I-V against brightness;

Figures 16a and 16b illustrate energy levels in two example devices;

Figure 17 plots the current density through devices I-V against applied voltage;

Figure 18 plots the drive voltage for devices I-V against brightness;

Figure 19 shows the representative performance of device X;

Figure 20 shows the representative performance of device Y; and

Figure 21 shows a representative performance of device Z.

Detailed Description

In a first example, a device is fabricated on a commercial 1x1 cm^2 ITO (indium-tin-oxide)-glass substrate (Balzers). Referring to Figure 1, such an exemplary substrate is shown in which an ITO layer 4 is formed on a glass substrate 2. For all chemical treatment steps in this first example, the substrate is held in a vertical configuration on PTFE substrate-holders. The solvents used in this example are of HPLC grade or better, unless